Original article

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The time of the optimal sighting condition after a blink

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blink, sport shooting, aiming time, best visual situation/quality, tear film

Abstract

Purpose: To measure the aiming time of sport shooters in relation to the last blink.

Methods: Eight experienced shooters were examined (5 men and 3 women, mean age was 38.4±9.8 years) during indoor sport pistol shooting range. We measured the time between the last spontaneous blink and the moment of shooting. Three shooting sessions per subject and an average of 10 shots per practice session were recorded with a digital camcorder. The tear film break-up time (BUT) and the Schirmer I test were determined. All the results were analyzed with a multiplicative mixed model.

Results: A total of 239 shots were analyzed. The average time interval between the last blink and the shooting was 5.25 seconds (95% confidence interval: 4.23-6.53 seconds). In the three shooting sessions, the mean time interval between the last blink and shooting was similar in every subject. It did not show significant difference and the intraclass correlation coefficient was 0.66 (95% confidence interval: 0.25-0.91). The age, gender, BUT and Schirmer I test did not correlate significantly with the time interval between the last blink and shooting.

Conclusion: The average aiming time of shooting was 5-6 seconds after blink, and as it was similar to the time needed to reach the most regular ocular surface after blinking in our earlier study, it might be in connection with the best visual quality of this period of time.

Introduction

Blinking is a natural and essential process to maintain the physiological state of the human eye. After eye opening, the quality of the viewed picture varies second by second. After blink, improvement of the vision due to fixation by fine eye movements, accommodation and disaccommodation, changing of pupil diameter, tear film kinetics and the temporary course of them determinates the time when the optimal visual situation occurs. *Ehrmann et.* al found that the visual acuity improved in the first 400 ms after blink, reached 100% of the own best visual acuity and stilled over 90% in the next one and a half seconds. (*Ehrmann et al*., 2005)

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In our earlier study we showed that after blinking there is a so called tear film build-up process and the ocular surface reaches its best surface regularity and possible the best visual acuity around 3-7 seconds after a blink.

In this study, we wanted to assess the time needed for developing of the optimal visual situation. We chose a situation in which people expected to act in accordance with the quality of the viewed image and this action can be examined objectively. In a number of previous studies, the behavior of the human eye was examined during different sport activities, so we asked for a contribution of experienced sports pistol shooting competitors to this investigation. A special portion of the time spent on aiming, namely the time interval between the last blink and the moment of shooting was measured during the target practice.

Methods

Ten experienced sport pistol shooting competitors were enrolled in this prospective study which followed the tenets of the Declaration of Helsinki. All of the participants, who gave their consent, were informed of the general nature except the specific purpose of the examination (determination of the aiming time). The study was approved by the Semmelweis University Regional and Institutional Committee of Science and Research Ethics.

During the participation in sport pistol shooting practice, subjects were recorded with a digital camcorder (Sony DCR-PC100E, Sony Corp., Japan). Every subject was experienced in shooting and pistol use. We recorded 3 practice sessions per person with an average of 10 shots per session. At least one day was passed between two practice sessions of every subject. All practice sessions took place in the late afternoon and every shot was carried out at a distance of 15 m from the target in the indoor pistol shooting range as it was familiar to the participants. The aiming time was defined as the time between the last blink and the moment of the shot. Records were analyzed with a time-resolution of 12.5 frames per a second. An eyelid movement was regarded as a blink in case the center of the cornea was covered by the upper eyelid. The moment of the shot was defined as the starting point of the sound-wave.

Each of the participants underwent a slit lamp examination of the anterior segment, and their uncorrected and best corrected visual acuity was determined. The tear status was assessed by measuring the tear film break-up time (BUT) three times per eye with a fluorescein-imbided strip technique and by means of the Schirmer I test after 5 minutes without anesthesia. Subjects, whose results showed less than 10 seconds as average BUT or 10 mm as average Schirmer I test, were excluded, respectively.

Data analysis was performed with a commercial statistical software package (SPSS, ver. 12.01 and ver. 15.0 for Windows, SPSS Inc., Chicago, IL). The mean aiming time was determined. The p values< 0.05 were considered statistically significant.

Results

Two participants were excluded from the examination because of their abnormal BUT or Schirmer I test results. The mean age of the remaining eight subjects (5 men and 3 women) was 38.4±9.8 years. None of the participants had any known ophthalmic disease. The average BUT and Schirmer I test result were 20.6±12.9 seconds and 23.1±5.9 mm, respectively. The average temperature and humidity were 13.5±2.5 °C and 31.9±7.8%, respectively.

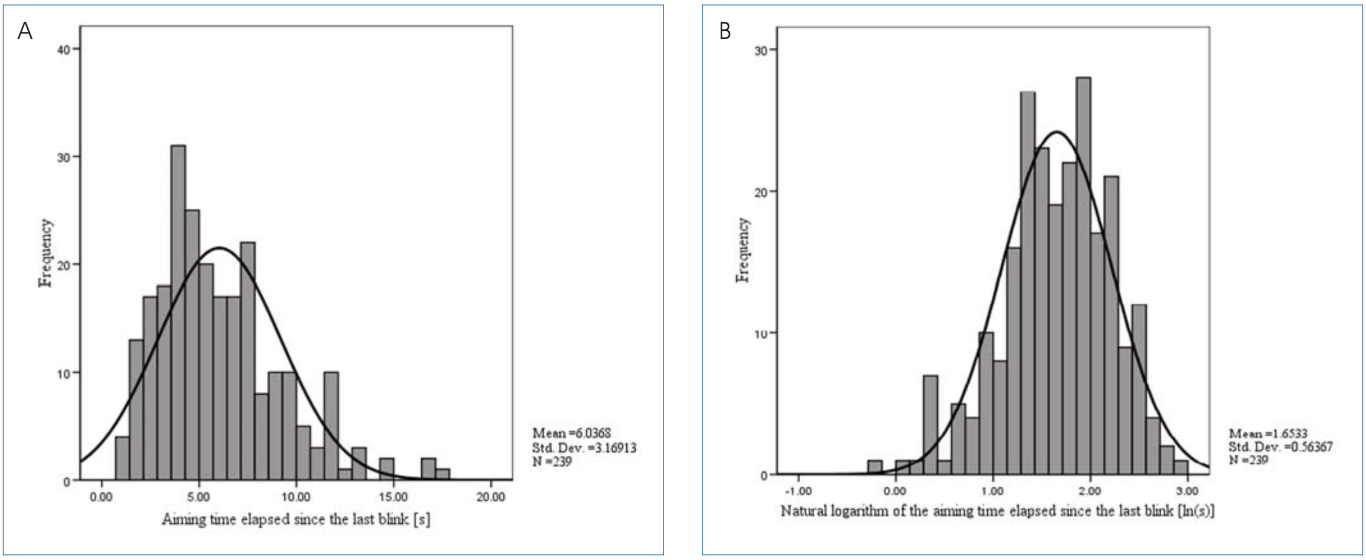

Figure 1. The histogram of the aiming time (A) demonstrates a distribution skewed toward positive values, but the histogram of the natural logarithm of the aiming time (B) displays a nearly normal distribution.

Table 1. Data the 8 participants, and the average aiming times per participant in the three different shooting practice sessions.								
Subject	**Age**	**Gender***	**Mean BUT (s)****	**Schirmer I test (mm)****	**Average aiming time per practice session±SD (s)**	**Number of shots per practice session**	**Overall average aiming time±SD (s)**	**Total number of shots**
1.	51	M	43.6	24	5.16±1.14	11	5.96±1.61	31
					5.87±1.40	9		
					6.83±1.84	11		
2.	53	M	20.1	30	4.24±0.87	10	4.61±2.14	31
					6.82±2.04	10		
					2.94±1.13	11		
3.	37	M	16.1	16	10.55±2.45	9	9.08±2.48	29
					8.58±2.24	10		
					8.26±2.38	10		
4.	36	M	37.8	17	5.42±1.60	10	5.52±2.17	30
					5.98±2.27	10		
					5.14±2.65	10		
5.	30	F	12.9	24	4.23±1.36	10	3.54±1.11	30
					3.55±0.70	10		
					2.84±0.74	10		
6.	29	M	10.0	18	7.56±3.82	9	8.55±4.49	29
					12.10±4.13	10		
					5.90±3.13	10		
7.	28	F	10.3	30	4.84±2.14	10	3.94±1.63	30
					3.89±1.11	10		
					3.09±1.03	10		
8.	43	F	14.1	28	6.60±2.29	10	7.37±3.24	29
					8.58±3.58	10		
					6.88±3.70	9		

*M=male, F=female. **Average value for the two eyes. SD=standard deviation. s=seconds

The measured aiming times shorter than 0.5 seconds were excluded because blinking immediately before and after the shot was considered as reflex blinking. This exclusion involved only 2 of the 239 shots analyzed during the study. Results were subjected to an analysis with mixed models. (Brown et al., 2006) The appropriateness of the models was analyzed on the basis of residual plots. For accurate evaluation of the mean aiming time, we took certain random and fixed effects into account. The random effects were the individual mean aiming time of each participant, the dates of the shooting practices and the repetition. The fixed effects involved the gender, the age, the BUT and Schirmer I test results of the participants such as the humidity and the temperature measured during each practice session. Distribution of the measured aiming times appeared to skew toward positive values *(Figure 1A)*, and after fitting an additive mixed model, the variability of the residuals (the difference between the modeled aiming times and the actual values) increased with the modeled data *(Figure 2A)*. In a multiplicative model in which the natural logarithms of the effects were added, the residual plot did not show a typical pattern which indicated the required fitting of the model to the data *(Figures 1B and 2B)*. Consequently, the multiplicative model was used for describing the data. According to the multiplicative model, the average aiming time was 5.25 seconds and the 95% confidence interval was 4.23 - 6.53 seconds *(Table 1)*. None of the fixed effects presented a significant correlation with the aiming time ($p>0.05$). In case of each participant, the aiming times in the three different practices did not show significant differences. The intraclass correlation coefficient (ICC) of the mean aiming time in the three different session was 0.66 (95% confidence interval was 0.25 and 0.91, $p=0.002$). The mean aiming time and the standard deviations of the aiming time in case the two excluded subjects were 6.38±1.46 seconds and 8.33±3.36 seconds.

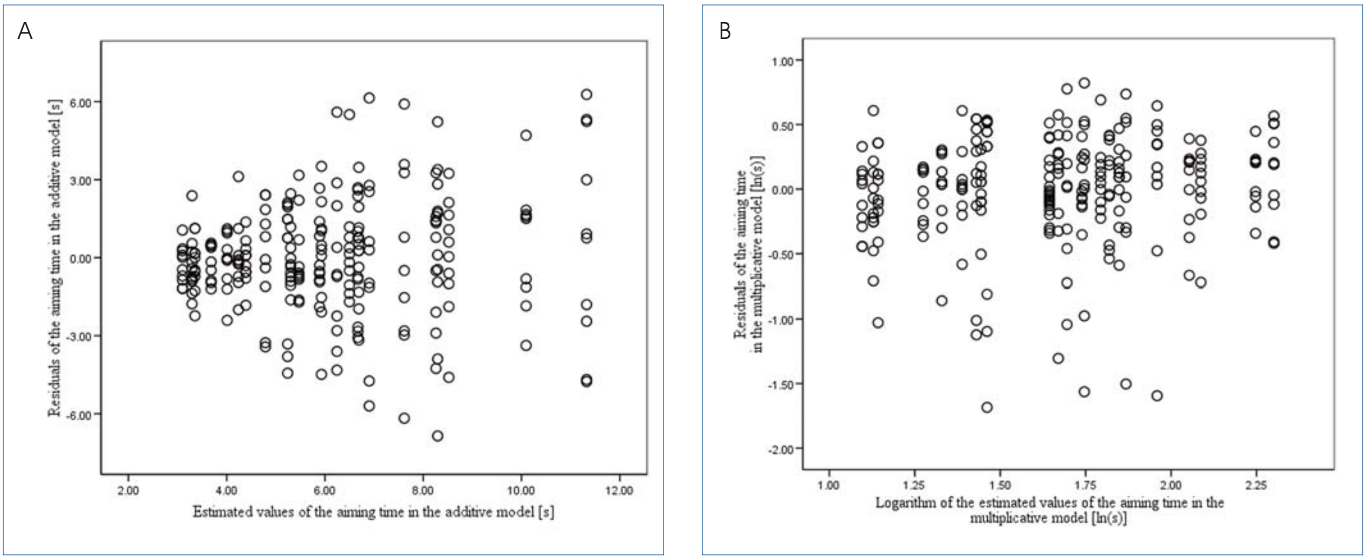

Figure 2. The residual plot in the additive mixed model (A) and in the multiplicative mixed model, which uses the natural logarithms of the data (B). The residuals were the differences between the modeled aiming time and the measured values. With the additive model, the variability of the residuals increased with the modeled aiming time, but the residual plot did not show a typical pattern with the multiplicative model. This denoted the good fitting of the multiplicative model to the measured data.

Discussion

Examination of visual conditions during a sport activity was not unique in the ophthalmologic literature. Many kinds of sports (e.g. basketball, golf, shooting etc.) required continuous visual control; however, optimal visual acuity was not the absolute condition of the successful outcome in these sports. (*Applegate et al.*, 1992, *Bulson et al.*, 2008) Therefore, we did not evaluate the results of the shooting performance in this study.

Our present results demonstrated that the aiming process which required great concentration took about 5 seconds after a blink. The mean aiming time was considerably longer than the previously estimated time (0.4 s) which was needed to reach the best visual acuity after blink in experimental target recognition test (*Ehrmann et al.*, 2005), however were very similar to the time needed to reach the most regular ocular surface after blink, as we found in our earlier study. (*Németh et al,*. 2002)

During the aiming process, the participants tried to overlap the target at 15 m distance and the orientation of the bearing of the sport pistol at about 0.8 m distance (the average length of the human arm). For this, repeated accommodation and disaccommodation processes with about 1.25 D amplitudes were needed. *Kasthurirangan et al.* found significant differences in accommodative and disaccommodative dynamics between young and old population. (*Kasthurirangan et al.*, 2006) While the speed and the maximum amplitude of accommodation decreased and the latency of disaccommodation increased with age, the speed of disaccommodation and the latency of accommodation did not change with it. In our study, the age of subjects in the examined population was between 28 to 53 years and the aiming time did not show significant correlation with age. Disregarding the age dependent differences, the mean latency of accommodation and disaccommodation in case of about 1 D stimulus was about 0.4 seconds and the mean time constant was about half a second. (*Kasthurirangan et al.,* 2006) During the 5 seconds several repeated 1 D accommodation and disaccommodation process were able to happen. Pupil contraction follows the blink with about 250 ms latency, the contraction is caused by the typical light response of the pupil. (*Cox et al.*, 1992) Later the pupil diameter followed the accommodation processes.

After eye opening, considerable changes also took place on the ocular surface too such as building up of precorneal tear film, the three layer of tear spread over the anterior surface. *Owens et. al.* found that the average time of the tear stabilization was 1.05±0.3 seconds using the movement of lipid particles as indicator of tear spreading. (*Owens et al.*, 2001) In study of Goto et. al, the mean lipid spreading time measured with interferometric methods was 0.36±0.22 seconds in healthy subjects. (*Goto et al.*, 2003) Although, directly visible tear spreading stopped up to one second after blink, the indirect methods showed longer alterations on the anterior ocular surface. The precorneal tear film dynamics has an influence on the corneal topographic patterns. Németh et. al revealed that the ocular surface detected by corneal topography reached its most regular state (tear film build up) approximately 3 to 10 seconds (average 7.1±3.9 seconds) after eye opening. (*Németh et al.*, 2002) The corneal coma-like aberration RMS (root mean square) decreased significantly after blink similarly to the topographic surface regularity indices and the minimum aberration appeared about 6 seconds after blink. (*Montés-Mico et al.*, 2004) Nevertheless, the mean stimulated keratometric values of the cornea did not show changes after blink. (*Erdélyi et al.*, 2006) The precorneal tear film has great impact on the optical quality of the eye. It was demonstrated entirely in previous studies that the optical image quality decreased significantly during the tear film break up; nevertheless, the visual acuity and the threshold reading on static perimetry improved after instilling artificial tears in dry eye patient. (*Tutt et al.*, 2000, *Rieger*, 1992, *Albarrán et al.*, 1997) Accordingly, it is presumable when the precorneal tear film reached the most regular and stable state and the higher order aberrations of the cornea and the whole eye decreased, the retinal image quality improved significantly. (*Németh et al.*, *2002, Montés-Mico et al.*, 2004, *Koh et al.*, 2006) Results of *Montés-Mico et al.* supported this hypothesis. *(Montés-Mico et al.*, 2005) They found that the objective modulation transfer function (MTF) of the eye at higher spatial frequencies reached the optimal level approximately 6 seconds after a blink. The mean aiming time was 5.25 seconds in our study, which was similar to the time of tear film build up of Németh et al. and optimal MTF of *Montés-Mico et al.* after blink.

Our results suggest that the optimal visual quality becomes optimal in a similar time after blink under natural conditions as in sport aiming situation. The most important feature of our study was that we monitored only the behavior of subjects while they were taking aim during pistol shooting under familiar circumstances for them as they all were experienced sport pistol shooter competitors. Thus, our study lends support to the previous results with data obtained under conditions closer to the everyday-life. In spite of the fact we were not able to prove significant relation between the aiming time and results of Schirmer I test and tear film break up time, the impact of the tear film build up might be dominant in this process. However, the duration of repeated accommodation and disaccommodation process during aiming was not negligible.

Blinks detected in the present examination were spontaneous, since the participants were aware of the video recording, but they did not know the specific aim of the study. Spontaneous blinks are partly incomplete (*Doane*, 1980), as we saw in our own records, and they are less forceful than voluntary blinks. Blinking mechanism is important in the maintenance of tear film lipid layer. (*Korb et al.*, 1994, *Korb et al.*, 2005, *Benedetto et al*., 1984) Incomplete blinking will not express the Meibomian glands or reform those portions of the lipid layer that are not wiped by the blink; the tear layer over the un-wiped areas of cornea will continue to thin until re-wiped by a subsequent complete blink. (*Korb et al.*, 2005, *McMonnies*, 2007) The tear film build-up process might be closely connected with the lipid layer spreading on the ocular surface. According to these results, a difference may be presumed between the tear film build-up times after complete or incomplete blinks. Nevertheless, Erdélyi et al.did not find significant difference between tear film build up time measured by high-speed videotopographic method after complete and incomplete blinks. (*Erdélyi et al.*, 2006) The average aiming time in this study agreed well with the findings of previous studies in which the blinks were voluntary and complete. This confirms there might be no connection between the tear film build-up time and the completeness of blink. Though, we were not able to distinguish entirely between complete and incomplete blinks relying exclusively on the records because of the low time-resolution. Moreover, the participants were allowed to move freely and (for safety's sake) the record showed them not face to face, but in semi-profile.

The aiming time was described better by the multiplicative mixed model than by the additive mixed model. The aiming process could be influenced by other additional factors beyond the tear film dynamics, e.g. the present mental status, the individual routine and the harmony between the breathing rhythm, the cardiovascular system and the state of the muscles. In the mixed model, these factors are possible components of the random effects relating to the participants and the dates of shooting practices. The multiplicative character of the model indicates that these effects modify the typical aiming time with a random percentage instead of a random value.

Limitations of our study include the small number of participants and the fact that the mean aiming time might be longer than the real tear build-up time, because of the latency between the perception of the optimal visual conditions and the moment of shooting. However, this latency could be considerably shorter than the standard deviation of the average determined aiming time. Other limitation of our study was that we did not measured tear film build-up time of the participants, so direct comparison with the aiming time was not possible however it would be meaningful. Such individual comparisons would be able to exhibit the possible latency between the tear film build-up time and the aiming time.

In conclusion, the aiming time after blink in experienced shooters was found to be 5-6 seconds. The interesting question is: Why they use this time point spontaneously? Our hypothesis is: because this time period gives the optimal visual quality for them. The supporting facts are: a similar time point was found both in case of tear film build up time (improvement of the ocular surface regularity), the decrease of the higher order abberations and also in the objective modulation transfer function (MTF) of the eye at higher spatial frequencies. As all of them reached the optimal level approximately 6 seconds after a blink, we might suppose that the shooters are using this time period because it is the best visual condition after a blink.

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